Introduction

Reducing the Nuclear Danger is a primary mission of Los Alamos National Laboratory (LANL) and other DOE-DP laboratories with nuclear weapons containment as the heart of several programmatic goals. Major program activities in a variety of nuclear-related areas -- weapons, materials, nonproliferation, environmental restoration, and energy -- contribute to making the world a safer place.

The Critical Issues Forum (CIF) was established to give students and teachers the opportunity to address issues and circumstances involved in safeguarding nuclear weapons. As we first began to develop the CIF program, we made a conscious decision to develop a curriculum model that encompassed our educational philosophies and experiences as they pertained to successful teaching and learning practices. This model became the "Critical Thinking Curriculum Model (CTCM)."

We have developed challenging curricula in five areas focusing on the nuclear world. In addition, some of our former participating teachers have developed a few curricula areas based on the CTCM format. We hope you have a valuable learning experience as you participate in the topic area of your choice.

All of the nuclear world topic areas are inter-related and form the basis of five semester of work. Each curricula area requires teams of students to conduct academic research while they address specific task assignments. Completion of each assignment will prepare the students for the next assignment. The constructive nature of the program allows students the opportunity to build their knowledge base as they delve into real world issues. By the time students complete all the assigned tasks, they will have a much deeper understanding of not only the issue at hand, but also the world as a whole. As they investigate their chosen topic area, students will discover the connections between four domains, the scientific, the political, the economic, and the social/cultural.

A guiding principle of our efforts is perhaps best expressed by University of California, Santa Cruz, Professor John Schaar: "The future is not a result of choices among alternative paths offered by the present, but a place that is created-created first in mind and will, created next in activity. The future is not some place we are going to, but one we are creating. The paths are not to be found, but made, and the activity of making them changes both the maker and the destination." If we, as human beings, are to survive in the future we must make knowledgeable decisions about the directions we choose to follow.

Program Background

Data on teaching indicates that students don't learn science by absorbing information that has been given to them through lectures, but rather by constructing meaning out of experiences through opportunities provided by the teacher. Students tend to forget most of the facts given to them. Research based programs give the students the ability to retain these facts by affording them the opportunity to think critically, to work through problems logically, and to make connections to the real world.

Meaning is a human construction interacting with a social situation, we are constantly defining it for ourselves. But one must remember what John Dewey warned, to beware of regarding the child's point of view as "finally significant in themselves." (Dewey, 1902) Learning is the responsibility of the learner, but the teacher must guide the student into developing meaning from material and experience. That is why communication is so important, but not from a singular perspective. When a person can successfully explain a body of knowledge to others, we can say that this person has properly mastered this knowledge. In describing and explaining ideas to others, we need to communicate in a way that all listeners will understand as much as possible. We must realize that each listener will understand our words differently based on their previous experiences, thus these differences need to be considered.

Curriculum must be designed so that it reflects real life situations, especially in the area of science. So much fascinating science is at the fingertips of learners everywhere, and with the increase in affordability of technology, more and more is present in homes across America. The use of societal issues as an organizer for the science curriculum has been seen as a method of teaching science to counteract the concepts as distinct and unique disciplines of study. (Hofstein & Yager, 1986) Scientists in the real world cross over the barriers between disciplines all the time, and never operate solely in the area of science, but integrate the use of language, writing, content knowledge and application of processes.

The curriculum needs to be integrative and students need to apply their learning, and curriculum development should be "a complicated and continual process of environmental design." (Apple, 1995) There should be a multidisciplinary approach that includes the integration of subjects, which should emphasize education as a process and not a product. The teacher needs to assume the role of facilitator and guide students through the curriculum. In this approach, student interests can fuel the framework for facilitating scientific concepts. As stated in <u>Science For All Americans</u>, "Concepts are learned best when they are encountered in a variety of ways, for that ensures that there are more opportunities for them to become embedded in a students knowledge system." (Rutherford, 1984)

An important insight in the design and development of curriculum and instruction is that content is nothing more nor less than a mode of thinking, a way to figuring something out, a way of understanding something through thought. There is no way to figure anything out without thinking. A typical school subject is seen as an area of content important to our society and the development of a "good" citizen. All content involves concepts and there is no way to learn a body of content without learning how to use it in thinking something through to a conclusive end. But content is also logically interdependent. To understand one part of some content requires that we figure out its relation to other parts of that content.

Content is currently approached as a sequence of "stuff" to be routinely covered and committed to memory. When content is approached in this lower order way, there is no basis for intellectual growth, no development of deep structures of knowledge, and no basis for long term grasp and control, thus no true understanding of the content.

Instructional practices in today's classrooms - presenting information, assigning homework, giving quizzes and tests, asking questions, and conducting class discussions - present a convenient framework within which to cultivate the process and practice of thinking. But thinking is only part of the equation of learning, building understanding. To be good at something requires "practice". Athletes know this and constantly strive for perfection by honing their raw abilities and talent through practice. Just as athletes practice to excel in their sport, students must practice to excel in thinking and learning. Curriculum must give students the opportunity to practice learning through thinking, questioning, and researching, to practice working with others to build a deeper understanding of content through collaborative efforts.

Program Goals

- To provide opportunities to develop and apply critical thinking and problem solving skills on a complex problem of global significance.
- To promote cooperative learning through successful teamwork.
- To develop the connections between scientific concepts and everyday life.
- To increase understanding of the science process.
- To increase public understanding of the issues relating to the future of the nuclear world.

Implementation of the Program

Students and teachers apply to participate in the CIF program as research teams. These research teams (teacher/s and students) participate as a class during the academic year. To take full advantage of the program, teams interact with other teams and with subject matter experts using telecommunications. Participating schools determine their needs for developing electronic networks with fellow student researchers and volunteer scientists and technicians or other experts. The schools provide support to the program by providing administrative resources and participation, by encouraging the teams to share their research with the student body and the community, and provide the students with an academic credit for completion of the program.

The project-based curricula approach developed for the program allows for a deeper search into a topic, whether it is terrorism, the future of "things nuclear", volcanoes in the universe, or macro-invertebrate analysis in local streams and rivers. The teacher guides the student in developing questions for further investigation, recommending resource sites, and probing student understanding of a given topic.

The teacher becomes a colleague, as students give direction to their research. Collaboration, whether it be in the classroom or through contacting subject matter experts via e-mail, is vital to motivating students and providing relevance to their classroom activities. Today, it may be as simple as a scientist at a national laboratory or institute of higher learning answering student inquiries about photosynthesis, tropical species or tornadoes.

Telecommunications use in the classroom empowers the learner to develop shared understandings of content material and to construct knowledge that is measurable by the classroom teacher. As Gowan stated, "The student's power to control better his later experience is grounded not so much in the teacher's authority as in the student's understanding of how educative materials enhance and enlarge the range of experience." (Gowan, 1981)

Problem-based learning, the Socratic method, and concept mapping can be seen as tools that help make student work more explicit and their understandings more complete. Yet, the project-based curriculum presents unique challenges to the teacher since it is often more interdisciplinary and open-ended in comparison to a traditional classroom experience. "Although the faculty will not be able to anticipate all of the ways students will shape what they learn (nor do they wish to), there are some principles and interrelationships they hope to highlight." (Edmondson, 1995)

Teachers have always provided the basic education, the 3 R's; reading writing and arithmetic ... but there is also a fourth R - research. To gain the full benefits of telecommunication, students must be involved in research activities that are real world centered and integrated with specific skill applications. The new language in schools includes terms like Internet, e-mail, World Wide Web, Telnet, FTP and networking. For the Internet "to be used in a meaningful way, we need to embed the use of this tool into a context; our teachers must guide its use and provide direction to set the stage for deep learning, and not for gathering of disjointed information." (Rose, 1995) To this end, we developed curriculum focusing on the "nuclear world" for the Critical Issues Forum program to act as a model for teachers as they develop and refine their curriculums.

A teacher can begin lessons by brainstorming with students to identify topics of interest to them, in order that they may direct their own learning and buy into the education process. "Relinquishing control of the curriculum will allow students to become responsible for their own learning as they manage projects, direct research and publish their work." (NetLearning, p. 119) By using sources across the globe, students can readily see (and many times hear) the connection to the real world.

The first thing you need is "a good curriculum" focusing on the desired content area. Designing an effective CTCM based curriculum appropriate to your grade level may take some time but the results will be well worth the time and effort involved. You will find that through the process of facilitating the discovery of content via a well planned CTCM based curriculum and not relying on didactic delivery of content, your students will learn, understand and retain more. As your students begin to actively pursue learning, they begin to take on the responsibility for their own learning.

Second, we recommend that a class of fifteen students or greater be established. This allows more interaction and affords you, the teacher the opportunity to establish multiple cooperative groups of 4 to 5 student members. Rules should be established relating to individual contributions to each group and to the class as a whole. It should be emphasized that the whole class is working together to resolve the problem that will be given to them at the onset of the semester.

Third, the class should emphasize learning as a process and not a product. The curriculum needs to be integrative and students need to apply their learning. The class should be a multidisciplinary approach that includes the integration of subjects allowing students to begin to make connections of their schoolwork to real life. The teacher needs to assume the role of facilitator and guide students through the curriculum.

Fourth, you should make sure that the students have access to resource materials, both "traditional sources" and "electronic sources." This will require access to the Internet. Each classroom utilizing a CTCM based curriculum should have computers connected to the Internet available for student use. This allows for immediate use when student groups have need for information. You should be prepared to facilitate any information search to expedite the process. Students should learn that the computer is a tool to be used in the learning process, but it must be available when needed.

Fifth, you will need to develop appropriate rubrics to be given to the students for their use in planning, monitoring and assessing their own learning. Explain to them what you are looking for in the way of group interactions, individual contributions to the team, research skills, writing skills, etc. and that you will be using the same rubrics to assess them. Have rubrics available for each area so students will know what to expect. The students must practice to improve their learning skills just as they practice to hone their athletic skills. Your class must give students the opportunity to practice learning through thinking, questioning, and researching, to practice working with others to build a deeper understanding of content through collaborative efforts.

Many teachers are now using project-based curriculum with great success at all levels of instruction. The discovery process mirrors the work done by real world laboratory scientists, and the dialogue generated by this type of inquiry helps to refine questions, interpretation of data, and new areas of research. The teacher cultivates student interests, but the ownership of the project is squarely on the students.

According to Bloom's Taxonomy, learning occurs in six levels. We call these levels the higher order thinking skills. It is the responsibility of the student to be engaged in their own learning by addressing all six levels. These levels are:

- Knowledge - the lowest level where students observe and recall information. This includes knowledge of dates, events, places, and major ideas and would include mastery of subject matter. It is the basis for the other five levels.
- Comprehension - this level includes understanding of information, grasping meaning, being able to translate knowledge into new context, interpret facts, compare and contrast, order, group and infer causes, and predict consequences.
- Application - this third level indicates that the student is able to use information, methods, concepts and theories in new situations as well as being able to solve problems using required skills or knowledge.
- Analysis - this level has the student seeing patterns, organizing parts, recognizing hidden meanings, and identifying components.

- Synthesis - students should be able to use old ideas to create new ones, generalize from given facts, relate knowledge from several areas and predict or draw conclusions.
- Evaluation - the highest level has students comparing and discriminating between ideas, assessing value of theories and presentations, making choices based on reasoned argument, verifying the value of evidence and recognizing subjectivity.

Students should be responsible for their own learning and make sure that they are addressing all levels. In addition to learning at all levels, students are also responsible for the following:

1. Being collaborative/cooperative team member
   - assuming an active role
   - working with the teacher and other team members
   - contribute to overall team effort and product
   - Participate in Socratic dialogue
2. Conducting needed research
   - Contribute to task analysis
   - Brainstorm and decipher assigned tasks
   - Make decisions toward task assignments
   - Conduct "traditional source" research
   - Conduct "electronic source" research
   - Collect data and information including sources
   - Report back to group for discussion
3. Maintain daily journal
   - Keep step by step process of research
   - Record ideas and questions
   - Record personal reflections
   - Record all information found and sources
4. Provide feedback to all teacher requests
5. Demonstrate acquisition of knowledge during and at end of class
6. Conduct self-assessments through teacher provided rubrics, etc.

By addressing the above, the student takes on an active role in his/her own learning. Through group interaction, the student learns to cooperate and make decisions that affect the whole. The student assumes responsibility for completion of his/her assigned task and then shares the results with the other team members thus contributing to the whole. As an active contributing member of a team, the student begins to see that he/she is making decisions about their own learning.

Introduction to the Tasks

The Tasks address the goals of the program by engaging the student/teacher teams in research, critical thinking, communicating thoughts, and making connections. The tasks also provide a mechanism for assessment, both for the program coordinators and the classroom teachers. Each task builds upon previous skills and knowledge base which allows the student/teacher teams to construct meaning from seemingly unrelated material. Each task addresses the interaction between the following domains:

Scientific domain

The impact of science permeates throughout society and provides many of the advancements in civilization. Along with the advantages science may produce, it also contributes factors that can be seen as harmful or detrimental to given situations. The purpose of this domain is to identify the scientific components within a given issue and to uncover the basic concepts present. Science has a great potential to benefit societies and people everywhere by increasing productivity while decreasing long term effects.

Economic domain

The effect of the economics is widely apparent in issues where those with the money and power create the reality in which everyone else must live. Too often, the lack of fiscal resources drives those in need to desperate situations that may lead to conflict. Developing an understanding of the underlying needs and motives of individuals and special interest groups that contribute to the economics with a given issue is to understand a major driving force in the decision making process.

Social/Cultural domain

The beliefs that people hold and the ties that bind them together are at the heart of this area of study. Within a critical issue, people's belief systems affect the way they interpret events and the reactions they have to situations and the ways in which they interpret information. Whether it be in a religious, ethnic or diversity issue, the impact of this domain on a given issue is real and ever-present.

Political domain

Politics make the world go round, and the varying regimes that dominate an issue, whether it be local, national, or global, impact the decision making process. Much of the political domain centers on the impact of political

> systems and the identification of leaders and decision-makers. It is also an area where those that are involved in the process make the decisions that everyone else must learn to live with, and that without an awareness of the issues and the players, the chance to affect change is limited or nonexistent.

Each task is designed as an open-ended assignment allowing the student/teacher teams to explore and make sense of their world. The tasks provide the student/teacher teams an impetus to conduct research at a deeper level, requiring them to collaborate and question each other's thoughts. Each team then reaches a consensus, which is then submitted for publication on the CIF web site.

The tasks address objectives in the following areas:

- critical thinking,
- research skills,
- communication skills,
- scientific process,
- interdisciplinary nature of the issue,
- community involvement.

Select a topic area and proceed with the assigned tasks in sequence.

Building a Historical Perspective of the Nuclear World

During this semester, students will build a historical background of how the world arrived at this point in time regarding nuclear science. Before students can make decisions regarding the futures of nuclear things, they must be well versed in what led to our present situation and confrontations. Students will examine a number of questions while considering the four domains.

Task #1 - The Early Years - focus on pre-1800
Task #2 - The Golden Age of Science - focus on early and mid-nineteenth century
Task #3 - The Era of Hope and Promise - focus on late nineteenth and early twentieth centuries and the discovery of radiation
Task #4 - Splitting the Atom - focus on early to mid-twentieth century
Task #5 - The Manhattan Project - focus on mid-twentieth century and Manhattan Project
Task #6 - Beginning to End of the Nuclear Cold War - focus on Cold War Era and its legacy
Task #7 - Preparing for the Student Conference on the Nuclear World

Terrorism in a Nuclear Age

During the semester, students will build an understanding of the issues surrounding the topic of terrorism. Students will examine the many facets of this global issue through a series of open-ended tasks.

Task #1 - Foundations of Terrorism
Task #2 - Types and Methods of Terrorism
Task #3 - Motivation and Making Sense of Terrorism
Task #4 - The Media and Terrorism
Task #5 - Security and Monitoring
Task #6 - Future Outlook
Task #7 - Preparing for the Student Conference on the Nuclear World

Proliferation of Nuclear Weapons

During this semester, students will build an understanding of the issues surrounding the topic of proliferation vs. nonproliferation. Students will examine the many facets of this global issue through a series of open-ended questions.

Task #1 - Motivation for proliferation or nonproliferation
Task #2 - Technology
Task #3 - Global Concerns
Task #4 - Future Solutions
Task #5 - Preparing for the Student Conference on the Nuclear World

Storage and Disposition of Nuclear Materials

During this semester, students will build an understanding of the issues surrounding the topic of radioactive waste materials. Students will examine the many facets of this global issue through a series of open-ended questions.

Task #1 - Use of Radioactive Materials
Task #2 - Types of Radioactive Waste
Task #3 - Issues and Concerns
Task #4 - Laws and Regulations
Task #5 - Options
Task #6 - Preparing for the Student Conference on the Nuclear World

The Future of the Nuclear World

During the semester, students will build an understanding of the issues surrounding the topic of the nuclear worlds future. Students will examine the many facets of this global issue through a series of open-ended tasks.

Task #1 - focus on current nuclear events
Task #2 - focus on future world environments in general
Task #3 - focus on future world environments, specifically energy
Task #4 - focus on role of nuclear things in future world environments, specifically weapons

Task #5 - focus on role of nuclear things in future world environments, specifically medical, industrial, and other applications

Task #6 - focus on public attitudes and institutional responses to technology in the future with emphasis on nuclear things

Task #7 - Preparing for the Student Conference on the Nuclear World